RADC-TDR-63-222



# AN ENVELOPE DETECTOR UTILIZING AN " IDEAL " DIODE

TECHNICAL DOCUMENTARY REPORT NO. RADC-TDR-63-222

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(Prepared under Contract No. AF30(602)-2331 by Quentin Veit, PHILCO CORPORATION, a Subsidiary of Ford Motor Co., Communications and Electronics Division, 4700 Wissahickon Avenue, Philadelphia 44, Pa.)

ABSTRACT

This technical note describes an "ideal" diode which was synthesized for use as an envelope detector in the receiver portion of the AN/TRC-56 multiplex. A functional description, circuit diagram, and test results are given.

## PUBLICATION REVIEW

**This report has been reviewed and is approved.**

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## I. INTRODUCTION

The AN/TRC-56 multiplex designed under Air Force Contract AF 30(602) 2331 utilized double-sideband transmitted carrier modulation. Stringent requirements were placed on the overall harmonic distortion within a channel. A design goal of overall harmonic distortion 50 db below the single channel test tone and an absolute maximum of 40 db below the test tone was set.

A sampling type of modulator was used in the multiplex transmitter to achieve low distortion in the modulation process.

In the multiplex receiver design, conventional diode detectors were first tried. Results were consistently poor. This was primarily due to the limited carrier input signal available (limited by power supply considerations) and the relatively low impedance loads placed on the diodes by the use of transistor amplifiers.

The next design tried used a sampling type of demodulator. In this approach the received carrier was greatly amplified and used to drive a trigger circuit. The trigger circuit provided rectangular pulses at the carrier frequency for sampling of the incoming amplitude-modulated carrier. This approach was abandoned because of a lack of reproducibility. The results were quite dependent upon levels, transistor characteristics, and temperature. Apparently the limiting and triggering action converted some of the sideband information into frequency modulation of the sampling pulses, causing the distortion.

At this point, it was decided to synthesize an ideal diode and use it to envelope detect the received signal. The resulting design is described in the following sections.

## II. FUNCTIONAL DESCRIPTION OF THE IDEAL DIODE

The block diagram of the ideal diode is shown in Figure 1. As a positive signal (E in) is applied at the input it is amplified by the amplifier (-A) and a negative signal appears at point $P_2$. Diode $D_1$ becomes back-biased while diode $D_2$ becomes forward-biased. The circuit now appears as that of Figure 2 and is a negative feedback amplifier with a gain of $R_2/R_1$. The output is very linear, i.e. Eo equals $- R_2 Ein/R_1$, because the slight nonlinearity of $D_2$ is inside the feedback loop and is decreased by the amount of the negative feedback.

When the input voltage is negative, point $P_2$ (Figure 1) is positive and diode D1 becomes forward-biased and appears as a very low resistance. In this case, the output remains essentially zero because only a very small error voltage exists at point P1 and diode D2 in its back-biased condition prohibits the voltage drop across D1 from appearing at the output.

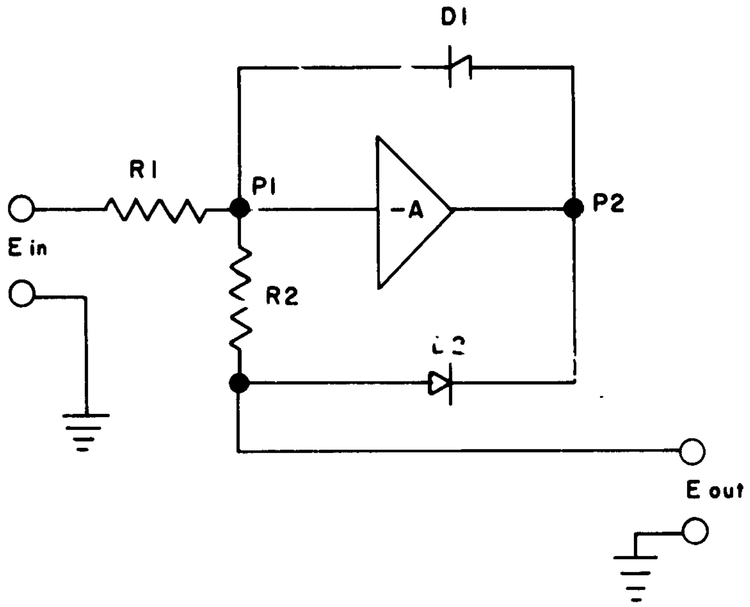


Figure 1

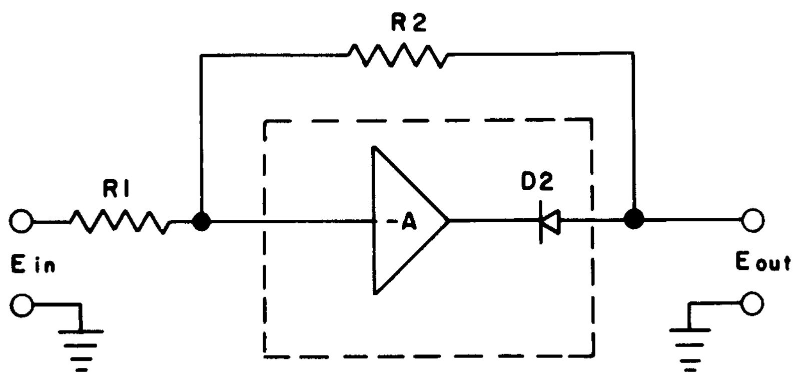


Figure 2

From the foregoing discussion it is apparent that the circuit performs as an ideal diode with the quality of the performance being primarily dependent upon the amplifier gain (amount of feedback) instead of the diode characteristics.

## III. CIRCUIT REALIZATION OF THE IDEAL DIODE

The circuit diagram of the "ideal diode" envelope detector used in the AN/TRC-56 multiplex is shown in Figure 3. Transistors Q1 and Q2 comprise the amplifier of the ideal diode. Transistor Q3 serves as an isolating emitter-follower to prevent loading of the ideal diode by the audio low-pass filter. The 56 uuf capacitor across the collector load of Q1 is used for stability reasons. Since Q1 and Q2 comprise a negative feedback amplifier the same gain-phase margin criteria applicable to a conventional feedback amplifier must be observed. A point of interest is that the amplifier consisting of Q1 and Q2 must be designed to pass the lowest modulation frequency contained in the carrier envelope.

The particular envelope detector described here was designed for a carrier frequency of 150 kc and an unmodulated carrier input level between 2 and 4 volts peak-to-peak. Later experimentation proved it capable of operating quite well at frequencies as high as 4 mcs.

## IV. TEST RESULTS

The envelope detector was evaluated in the system shown in block diagram form in Figure 4. The only available method for evaluating the detector required the use of an amplitude modulator to produce the signal to be demodulated. Therefore, the test results of necessity include harmonic distortion due to all components of the system. The best available modulator was the one designed for the multiplex transmitter and was used for the tests. The carrier amplifier was a vacuum tube unit employing extensive negative feedback and having less than 0.1 percent harmonic distortion at 40 volts peak-to-peak output level. Table I shows test results for two separate "ideal diode" detectors using the same test set up.

Table II contains test results for a third envelope detector with temperature as a variable. For this test, a different modulator than the one for the first two tests was used. This may explain the somewhat higher distortion values since the modulators were later found to require circuit modification to produce consistent distortion performance from unit to unit.

NOTE: The single channel test tone level produces 30 percent modulation of the carrier.

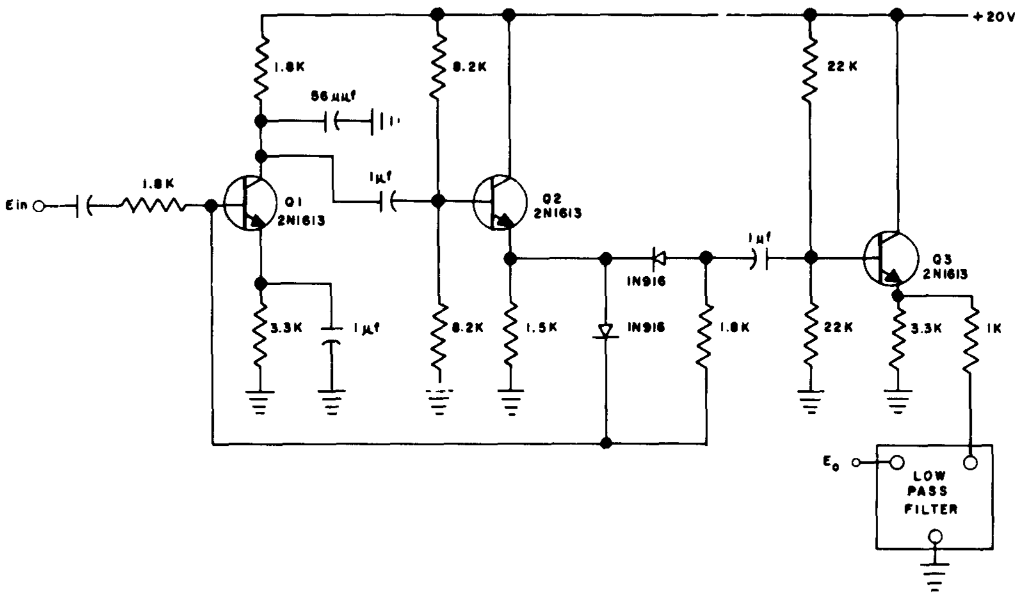


Figure 3. Envelope Detector Schematic

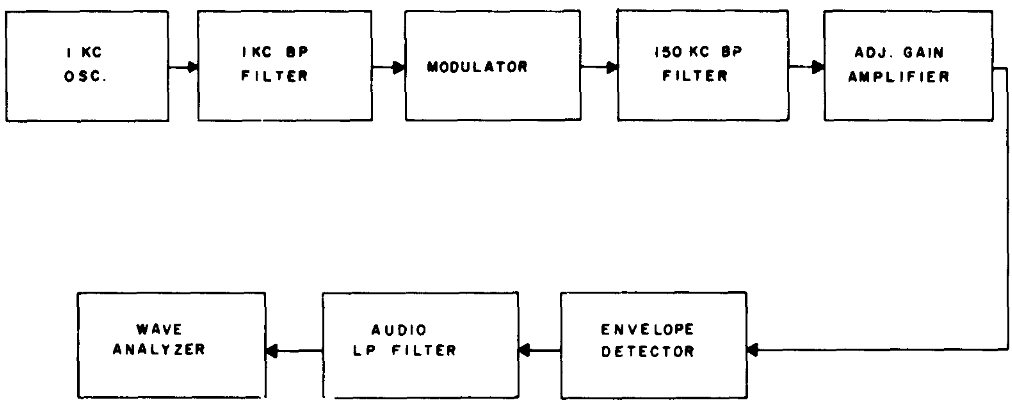


Figure 4. Block Diagram of Test Setup

## TABLE I

## DISTORTION PERFORMANCE OF "IDEAL DIODE" ENVELOPE DETECTOR

| | DETECTOR #1 | | | | | | | | | | | | DETECTOR #2 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Unmodulated Carrier Input - 2vp-p | | | | Unmodulated Carrier Input - 3vp-p | | | | Unmodulated Carrier Input - 4vp-p | | | | Unmodulated Carrier Input - 4vp-p | | | |
| Modulation | Second Harmonic | | Third Harmonic | | Second Harmonic | | Third Harmonic | | Second Harmonic | | Third Harmonic | | Second Harmonic | | Third Harmonic | |
| | % | db | % | db | % | db | % | db | % | db | % | db | % | db | % | db |
| 30% | .06 | -64 | -- | --- | .06 | -64 | --- | --- | .09 | -61 | --- | ---- | .06 | -64 | ---- | ---- |
| 40% | .08 | -62 | --- | --- | .08 | -62 | ---- | ---- | .12 | -58 | .03 | -70 | not meas | | not meas | |
| 50% | .10 | -60 | .05 | -66 | .09 | -61 | .03 | -70 | .15 | -56 | .04 | -68 | not meas | | not meas | |
| 60% | .13 | -58 | .08 | -62 | .11 | -59 | .06 | -64 | .17 | -55 | .07 | -63 | .11 | -59 | .06 | -64 |

Conditions: Room Temperature - Test Setup of Figure 4

## TABLE II

## DISTORTION PERFORMANCE OF "IDEAL DIODE" ENVELOPE DETECTOR AS A FUNCTION OF TEMPERATURE

| | Unmodulated Input - Carrier 2vp-p | | | | Unmodulated Input - Carrier 3vp-p | | | | Unmodulated Input - Carrier 4vp-p | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Modulation | Second Harmonic | | Third Harmonic | | Second Harmonic | | Third Harmonic | | Second Harmonic | | Third Harmonic | | Temperature |
| % | % | db | % | db | % | db | % | db | % | db | % | db | °C |
| | | | | | | | | | | | | | |
| 30 | .08 | -62 | ----- | ---- | .06 | -64 | --- | --- | .11 | -59 | .04 | -68 | 25 |
| 40 | .10 | -60 | .04 | -68 | .08 | -62 | .05 | -66 | .16 | -56 | .09 | -61 | 25 |
| 50 | .15 | -56 | .07 | -63 | .09 | -61 | .07 | -63 | .24 | -52 | .15 | -56 | 25 |
| 60 | .21 | -53 | .13 | -58 | .13 | -58 | .11 | -59 | .44 | -47 | .34 | -49 | 25 |
| | | | | | | | | | | | | | |
| 30 | .25 | -52 | .06 | -64 | .12 | -58 | .06 | -64 | .15 | -56 | .04 | -68 | -55 |
| 40 | .42 | -47 | .10 | -60 | .17 | -55 | .09 | -61 | .19 | -54 | .06 | -64 | -55 |
| 50 | .60 | -44 | .18 | -55 | .25 | -52 | .13 | -58 | .22 | -53 | .10 | -60 | -55 |
| 60 | .80 | -42 | .32 | -50 | .35 | -49 | .20 | -54 | .27 | -51 | .22 | -53 | -55 |
| | | | | | | | | | | | | | |
| 30 | .08 | -62 | --- | --- | .05 | -66 | --- | --- | .18 | -55 | .06 | -64 | 75 |
| 40 | .11 | -59 | .04 | -68 | .06 | -64 | .04 | -68 | .20 | -54 | .10 | -60 | 75 |
| 50 | .15 | -56 | .08 | -62 | .08 | -62 | .06 | -64 | .39 | -48 | .20 | -54 | 75 |
| 60 | .22 | -53 | .10 | -60 | .09 | -61 | .09 | -61 | .88 | -41 | .55 | -45 | 75 |
| | | | | | | | | | | | | | |

Table II - Distortion Performance of "Ideal Diode" Envelope Detector

As a Function of Temperature

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# CATALOGUE FILE CARD

Rome Air Development Center, Griffiss AF Base, N.Y. Rpt No. RADC-TDR-63-222. AN ENVELOPE DETECTOR UTILIZING AN "IDEAL" DIODE. 7p, incl illus, tables.

Unclassified Report

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1. Detectors
2. Amplitude Modulation

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III. Philco Corporation
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